MULTIVARIATE DYNAMICAL MODELING TO INVESTIGATE HUMAN ADAPTATION TO SPACE FLIGHT: INITIAL CONCEPTS

Mark Shelhamer[1], Jennifer Mindock[2], Tom Zeffiro[3], David Krakauer[4], William H. Paloski[1], Sarah Lumpkins[5]

[1]Human Research Program, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058
[2]Wyle Integrated Science and Engineering Group, 1290 Hercules, Houston, TX 77058
[3]Argosy Omnimedia, Rockville, MD 20852
[4]Santa Fe Institute, Santa Fe, NM 87501
[5]MEI Technologies, 18050 Saturn Lane, Houston, TX 77058

Abstract

The array of physiological changes that occur when humans venture into space for long periods presents a challenge to future exploration. The changes are conventionally investigated independently, but a complete understanding of adaptation requires a conceptual basis founded in integrative physiology, aided by appropriate mathematical modeling. NASA is in the early stages of developing such an approach.

Human Body in Space

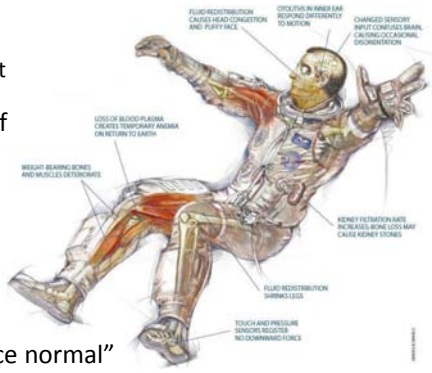
Example environmental stressors:

- Weightlessness
- Altered light/dark cycles
- Radiation exposure
- Isolation and confinement

Affect most systems of the body:

- Sensorimotor
- Cardiovascular
- Muscle
- Bone
- Immune

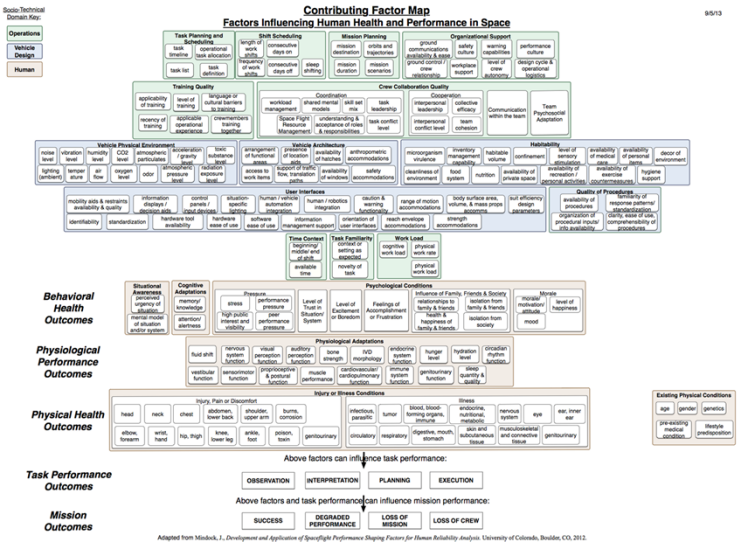
Effects of Space Flight on the Human Body



Adaptations lead to "space normal"

- Currently have a good understanding of individual system adaptations
- Many factors contributing to adaptations have been identified to provide system context

Need ***integrated*** understanding of how organism as a whole responds to spaceflight.



Unique features for integrated approach:

- Relatively homogenous astronaut population
- Environment well understood and monitored
- Ability to (within limits) make multiple simultaneous measurements in each person

Conceptual Approaches

Questions to pursue:

1) Does space-normal represent an attractor of a dynamic system, or a driven state maintained by chronic perturbation with dissipative costs?
2) Is there a "common currency" to describe the systems and their interactions?
3) Can the human response to space flight be characterized by bidirectional interaction with the environment?

One possible methodology – Small World Networks:

- Set of highly interconnected nodes in a system self-organize and are robust to perturbations
- Describe human body and countermeasure effectiveness in space? (e.g., exercise helps prevent bone loss and muscle deconditioning, but it may also benefit immune function and psychological health)

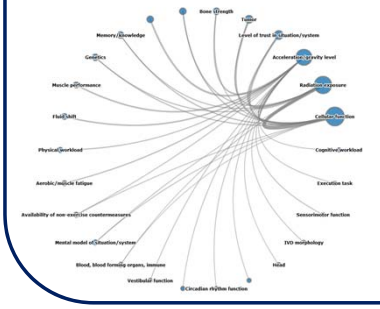
Advantages to the Approach

- Insight into complex interconnected systems in extreme environments
- Establishment of conceptual basis for human adaptation to space flight
- Improving approach to space flight countermeasures (e.g. interventions focused on critical network nodes may have widespread effects that replace a large number of interventions for individual system responses)

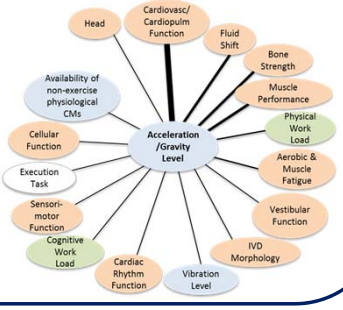
Initial Efforts

Developing tools to visualize and quantify linkages between disciplines covered by the NASA Human Research Program based on publication records.

Factors with potential linkages based on publication analysis:



Accel/Gravity linkages modeled after analysis evaluation:



Future Directions

- Develop capabilities to identify network nodes (factors) of high importance and strong system influence
- Develop capabilities to model countermeasures and their effectiveness on the integrated system state